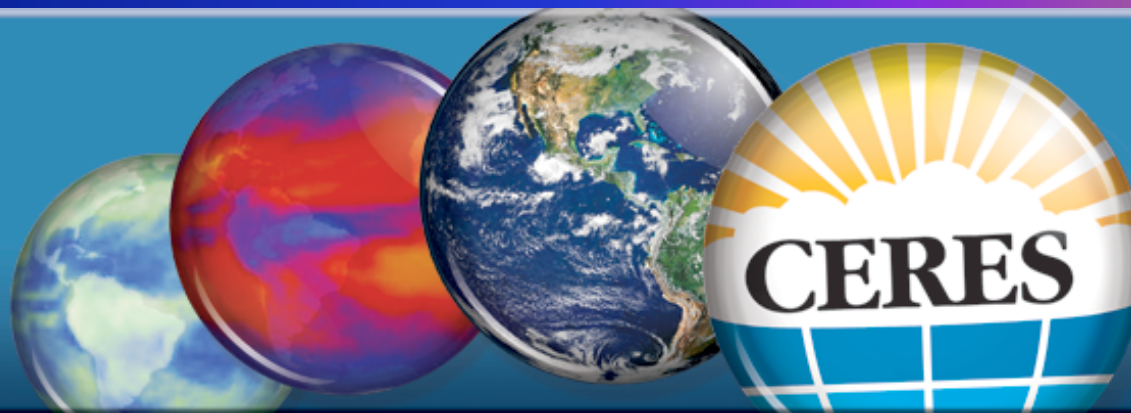


Clouds and the Earth's Radiant Energy System

Clouds and the Earth's Radiant Energy System

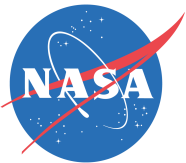


CERES FM1-FM6 Instrument Status Report

**Kory Priestley
&
Instrument Working Group**

**CERES Science Team Meeting
Geophysical Fluid Dynamics Laboratory
October 22, 2012**

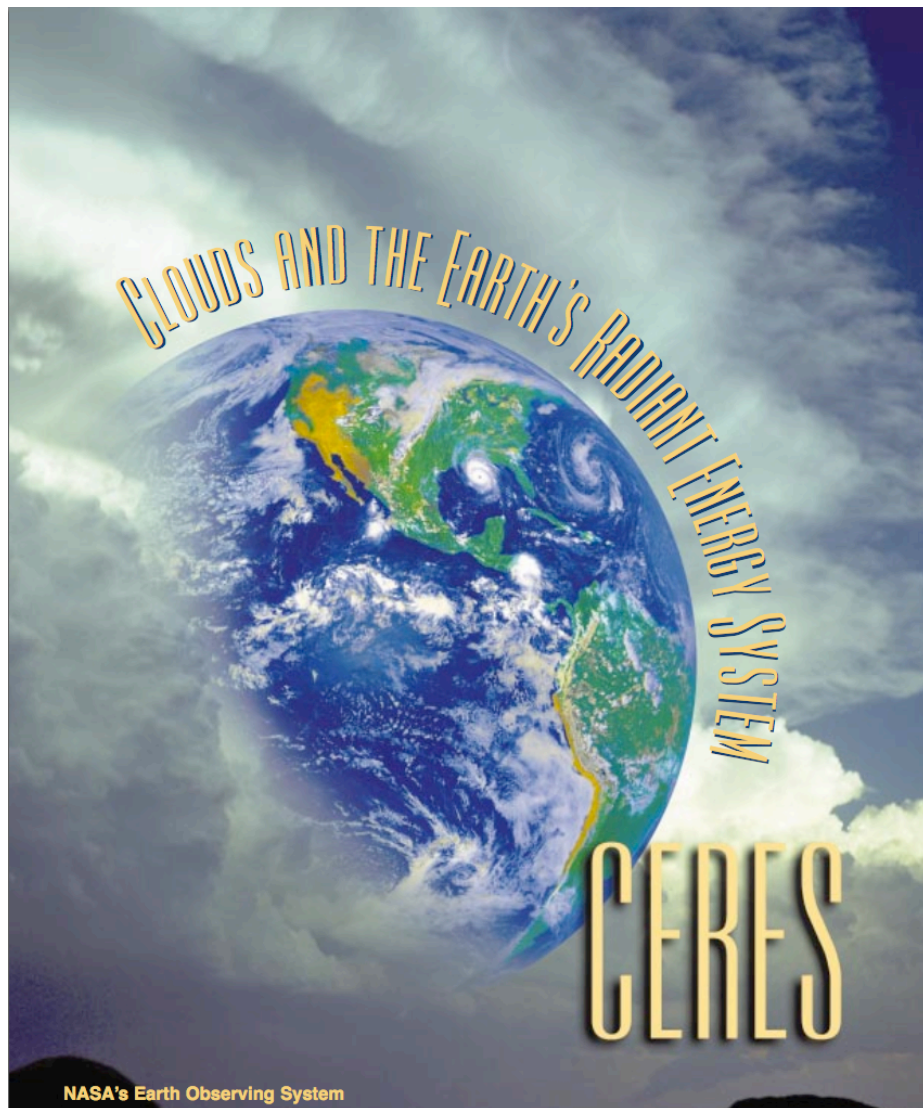




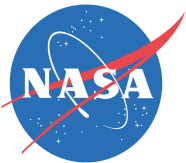
Discussion Topics



Clouds and the Earth's Radiant Energy System



- **CERES IWG Status**
 - Activities
 - Accomplishments
 - Future work
- **Instrument Status**
 - CERES Follow-on on JPSS-2
 - FM-6 on JPSS-1
 - FM-5 on NPP
 - EOS
- **Summary**



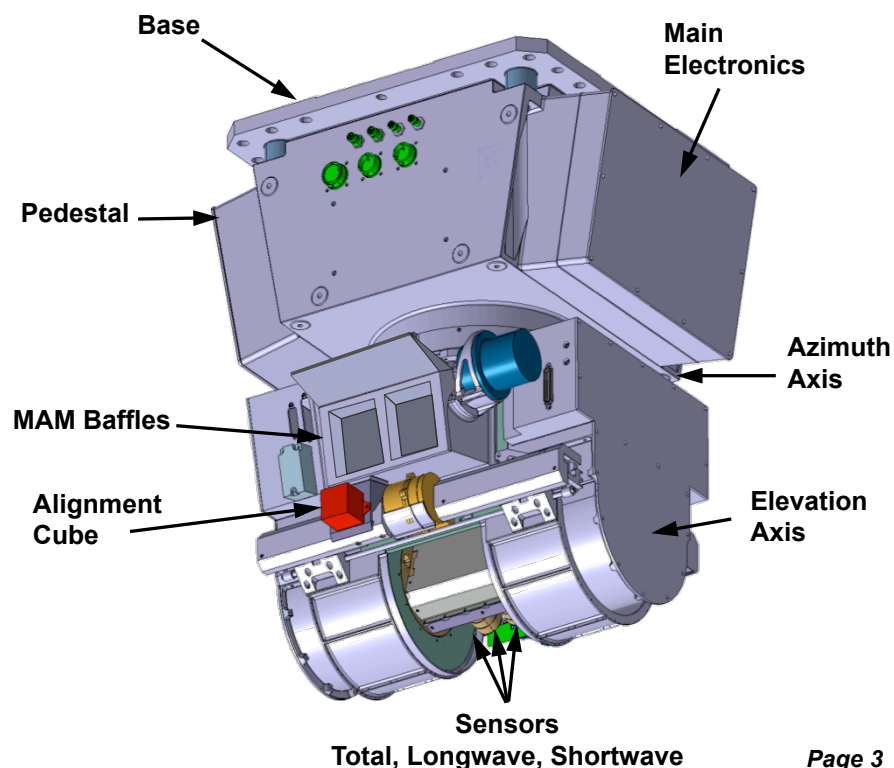
CERES Instrument

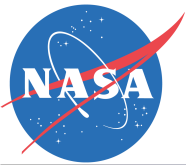


Clouds and the Earth's Radiant Energy System

- Designed, manufactured and tested by TRW, Redondo Beach, CA (currently Northrop Grumman Aerospace Systems)
- Contains three sensor assemblies with cassegrain optics and thermistor bolometer detectors
- Sensors measure thermal radiation in the near-visible through far-infrared spectral region
- Sensor channels are coaligned and mounted on a spindle that rotates about the elevation axis
- Hemispherical sampling obtained with an azimuthal axis drive system

Orbits	705 km altitude, 10:30 a.m. descending node (Terra) or 1:30 p.m. ascending node (PM-1), sun-synchronous, near-polar; 350 km altitude, 35° inclination (TRMM)
Spectral Channels	Solar Reflected Radiation (Shortwave): 0.3 - 5.0 μm Window: 8 - 12 μm , 5 - 40 μm (FM6) Total: 0.3 to > 100 μm
Swath Dimensions	Limb to limb
Angular Sampling	Cross-track scan and 360° azimuth biaxial scan
Spatial Resolution	20 km at nadir (10 km for TRMM)
Mass	45 kg
Duty Cycle	100%
Power	45 W
Data Rate	10 kbps
Size	60 x 60 x 70 cm (deployed)
Design Life	6 years





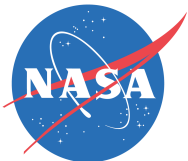
Enabling Climate Data Record Continuity



Clouds and the Earth's Radiant Energy System

Agency Roles and Responsibilities

Mission	Instruments	Responsible Agency (\$\$ in budget)		Implementation	
		Hardware	Science, Data Processing	Hardware	Science, Data Processing
EOS	PFM-FM4	NASA	NASA	NASA Procurement	NASA Science Team
NPP	FM5	NASA/ NOAA	NASA	NASA Procurement	NASA Science Team
JPSS-1	FM6	NOAA	NOAA	NASA Procurement	TBR
JPSS-2	CERES follow-on	NOAA	NOAA	NASA Procurement	TBR

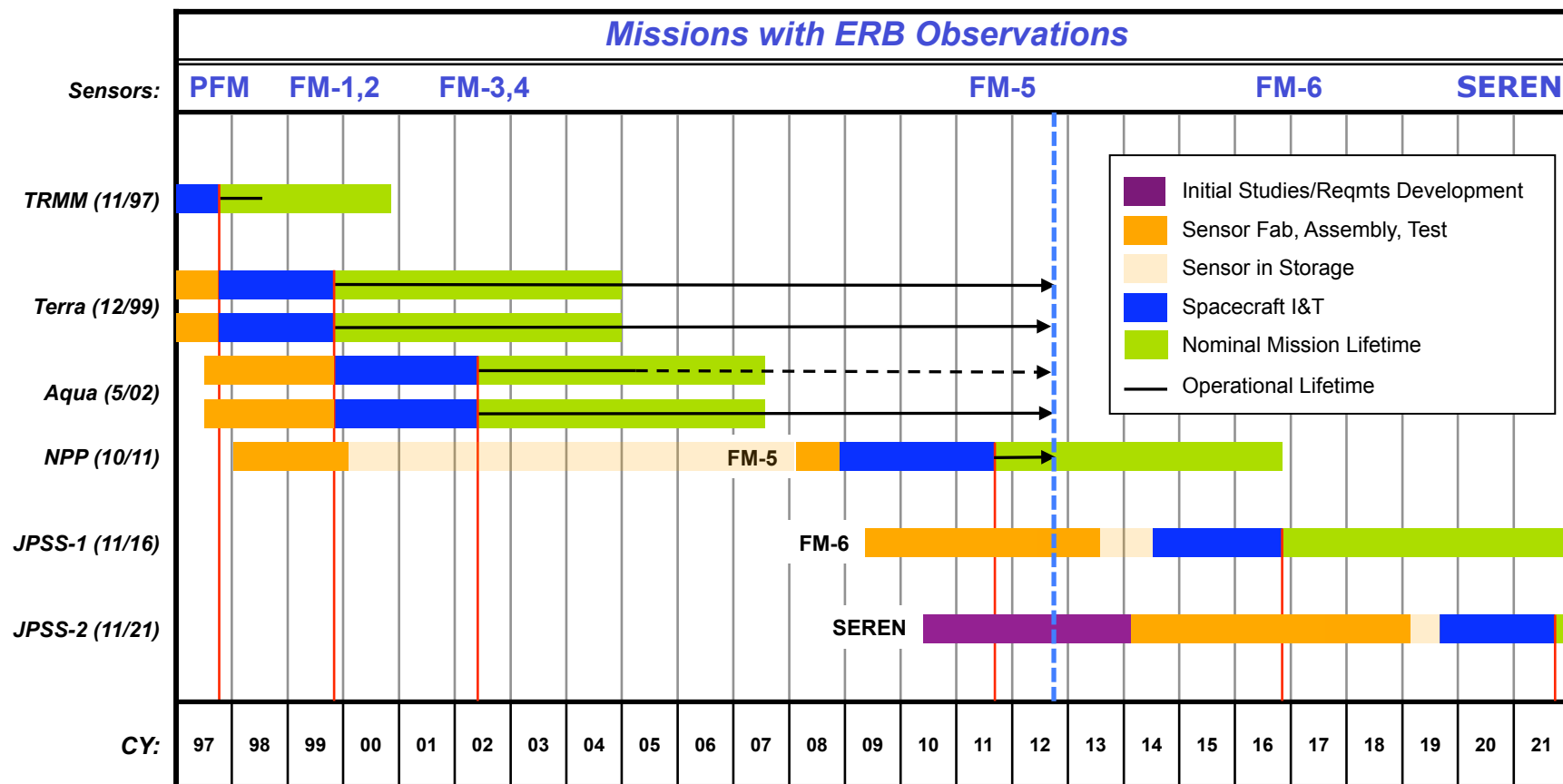


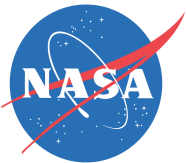
Enabling Climate Data Record Continuity



Clouds and the Earth's Radiant Energy System

CERES Flight Schedule





Instrument Working Group Personnel



Clouds and the Earth's Radiant Energy System

Cal/Val & LTM

- Susan Thomas -

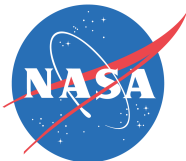
Phil Hess
Mohan Shankar
Nathaniel Smith
Nitchie Smith
Peter Szewczyk
Robert Wilson

Mission Operations & Engineering

- Bill Vogler -
- James Bailey -
John Butler
Janet Daniels
Christopher Gamboni
Mike Tafazoli
Kelly Teague
Christopher Brown*
William Edmonds*

Data Management

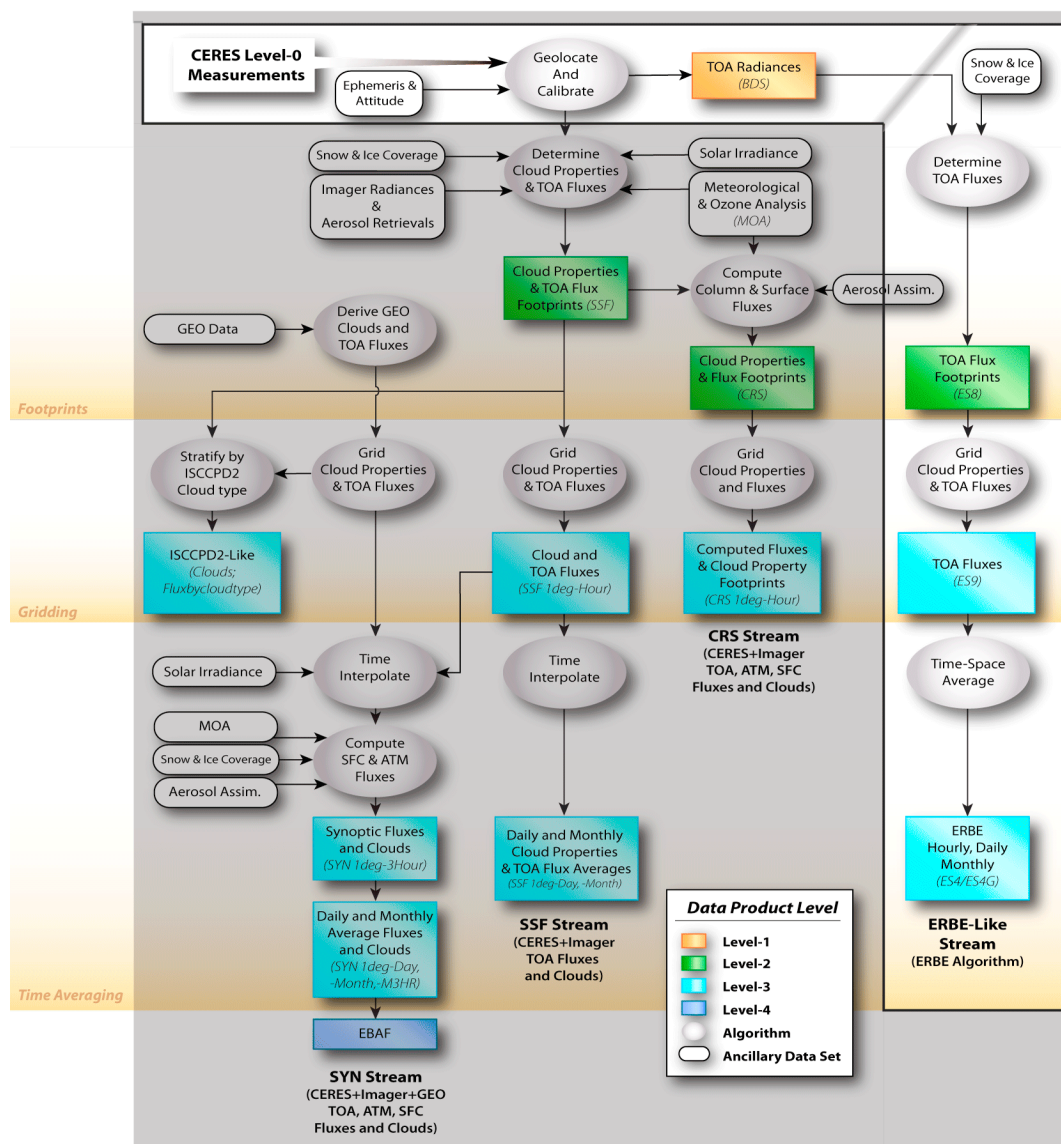
- Denise Cooper -
- Dale Walikainen -
Thomas Grepiotis
Jeremie Lande
Mark Timcoe
Nelson Hillyer*
Dianne Snyder*



CERES Processing Stream



Clouds and the Earth's Radiant Energy System





CERES

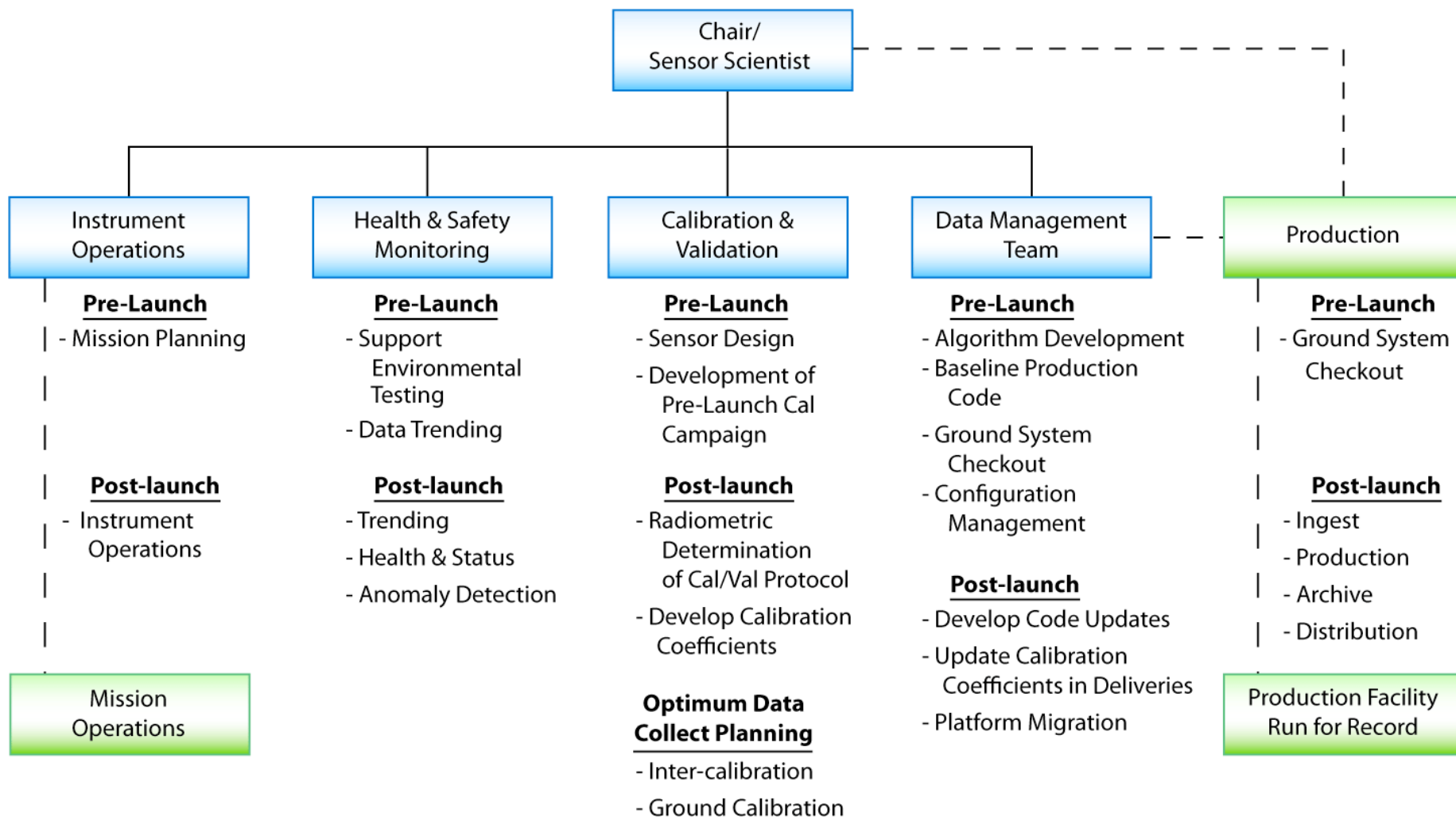
Instrument Working Group

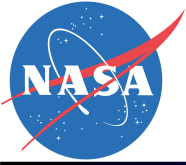


Clouds and the Earth's Radiant Energy System

— Authority

- - Coordination





IWG Activities : Products



Clouds and the Earth's Radiant Energy System

Missions on-orbit Terra/Aqua/NPP

Edition1_CV (FM1-FM5)

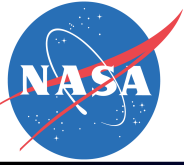
Daily QC Health and safety

Ingested by Cal/Val Protocol

Edition3 production (FM1-FM4)

Investigating feasibility of decreasing latency of data product release

Edition4 algorithm development (FM1-FM4)



Why is CERES Climate Quality Calibration so difficult?



Clouds and the Earth's Radiant Energy System

A question of time scales, experience and balancing accuracy with providing data products to the community.

- *Calibrated Radiances have been released on ~6 month centers*
- *6 months is just a blink of an eye when analyzing decadal trends...*

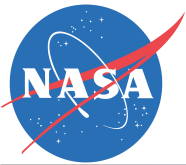
Same time scale as phenomena which influence instrument response

- *Beta Angle*
- *Solar Zenith Angle*
- *Earth Sun Distance*
- *Solar Cycle*
- *Orbital shifts*
- *Instrument Operational modes (e.g. RAPS vs. Xtrack)*

Design weaknesses and anticipated failures in onboard calibration hardware

- *full spectral range of observations not covered by cal subsystems*

Complicates separation of instrument 'artifacts' from natural variability.



Instrument and ERBE-Like Data Product Release Strategy



Clouds and the Earth's Radiant Energy System

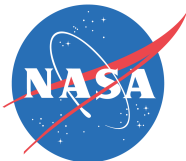
At_Launch - Static Algorithms and Pre-Launch coefficients - baseline product used during intensive Cal Val Period (Launch to SOC+8 Months)

Edition1_CV - Static Algorithms and coefficients - baseline product used in cal/val protocol (SOC+7.5 Months, continuous over mission)

Edition2 - Utilizes temporally varying coefficients to correct for traceable radiometric drift. All spectral changes are broadband and 'gray'. (L+1 yrs to ~5 yrs)

Edition3 - Will incorporate temporally varying spectral artifacts in the SW measurements. A complete re-analysis of Ground Calibration with additional component characterization measurements. (L+5 yrs)

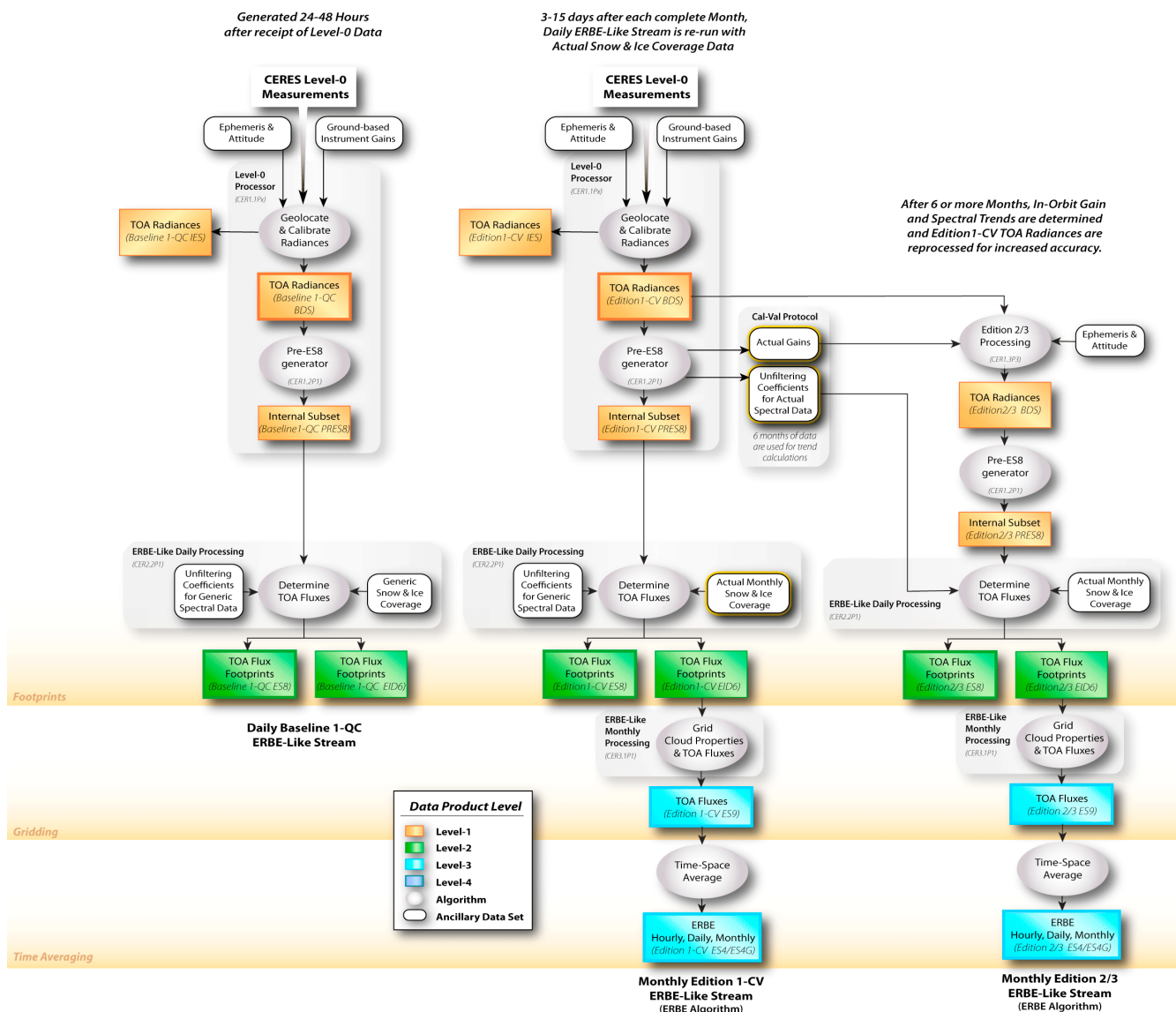
Edition2 products lag Edition1_CV by a minimum of 6 months

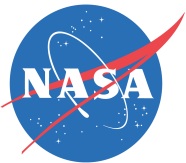


CERES IWG Processing Flow



Clouds and the Earth's Radiant Energy System



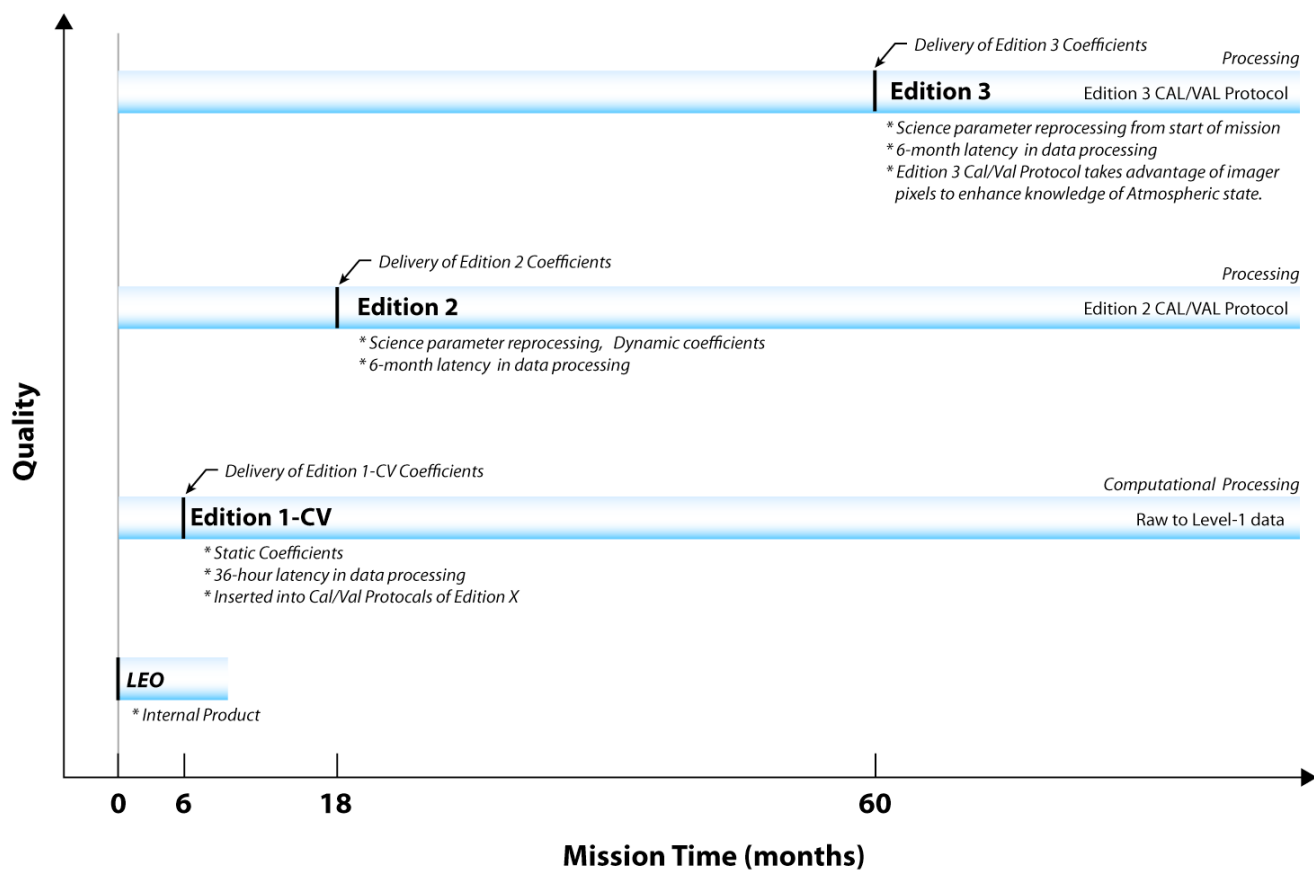


CERES IWG Product Flow



Clouds and the Earth's Radiant Energy System

CERES SDR Product Flow





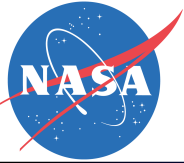
Terra/Aqua Instrument and ERBE-Like Availability



Clouds and the Earth's Radiant Energy System

Spacecraft	Product	Version	Available	Months Processed
TRMM	BDS	Edition1	Yes	1/98 - 8/98 , 3/00
	ERBE-Like	Edition1	Yes	1/98 - 8/98 , 3/00
		Edition2	Yes	1/98 - 8/98 , 3/00
Terra	BDS	Edition1CV	Yes	2/00 - present
		Edition2	Yes	2/00 – 6/10
		Editon3	Yes	2/00 – 12/11
	ERBE-like	Edition1CV	Yes	3/00 - present
		Edition2	Yes	2/00 – 6/10
		Editon3	Yes	3/00 – 12/11
Aqua	BDS	Edition1CV	Yes	6/02 - present
		Edition2	Yes	6/02 – 6/10
		Editon3	Yes	2/00 – 12/11
	ERBE-like	Edition1CV	Yes	7/02 - present
		Edition2	Yes	7/02 – 6/10
		Editon3	Yes	7/02 – 12/11
NPP	BDS	Edition1CV	Yes	2/12-present
	ERBE-Like	Edition1CV	Yes	2/12-present

Note: Red cells indicate datasets that are no longer in production.



IWG Activities : Operations



Clouds and the Earth's Radiant Energy System

Instrument Operations

- Instrument Operations team interacts with
 - 3 unique Mission Operations Teams
 - 2 unique Ground Systems

Aqua

- AMSR-E recovery operations

Across all Platforms

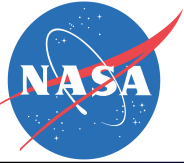
- Enhanced Target tracking capability (under development)
 - Increases sampling of specific geo-targets by 200x

FM-2

- Noise Spikes in Total Channel
 - Submux re-ordering patches developed
 - Ongoing monitoring during regularly scheduled Diagnostic operations

FM4

- MAM Cover Life test
 - Procs built to close MAM cover
 - Submux re-ordering patch developed to obtain high temporal resolution position data



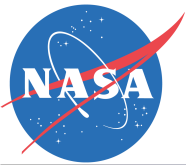
IWG Activities : Operations



Clouds and the Earth's Radiant Energy System

FM-5 Intensive Cal Val Campaign Complete

- Deep Space Calibration Pitchover Maneuver Complete
 - 4 Elevation Scan profiles and 1 sequence developed
- Lunar and Solar Calibrations initiated
 - 3 Flight loads developed to synchronize azimuth scanning to the A position
- Bleed Through in Analog to Digital Converter
 - 6 Bridge Balance logic patches for independent settings of the defined zero-point window for each of the 3 channels developed
- Resolution of stray light triggering False Sun-Present Events
 - 2 Memory patches developed altering the allowed mode for enabling the Solar Presence Sensor logic.
- Excessive drift rate in SW channel zero point
 - 6 short commands enabling the definition of bridge balance parameters for each channel via daily commanding developed
 - Eliminates the requirement to develop individual Bridge Balance Logic patches in the future, reducing risk and overhead.



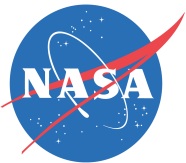
IWG Activities : Simulator Development



Clouds and the Earth's Radiant Energy System

•CERES JPSS-1 Simulator Design and Development

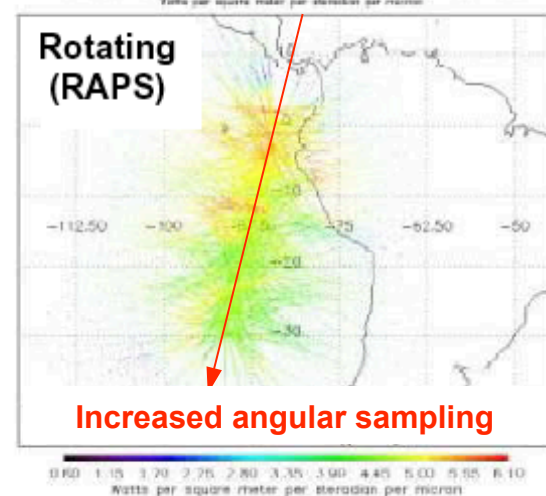
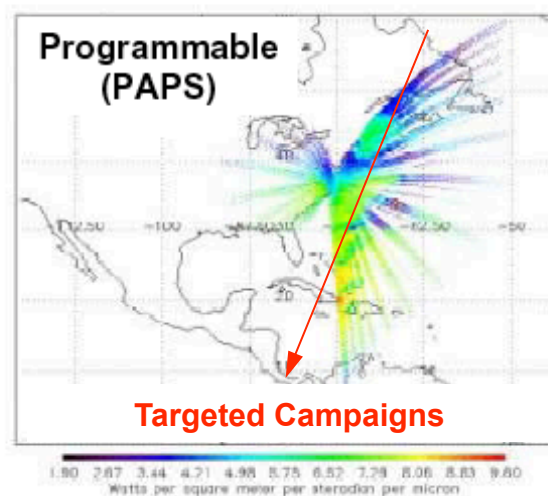
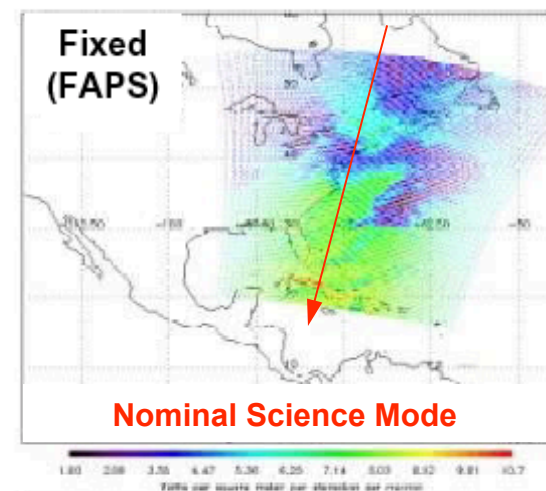
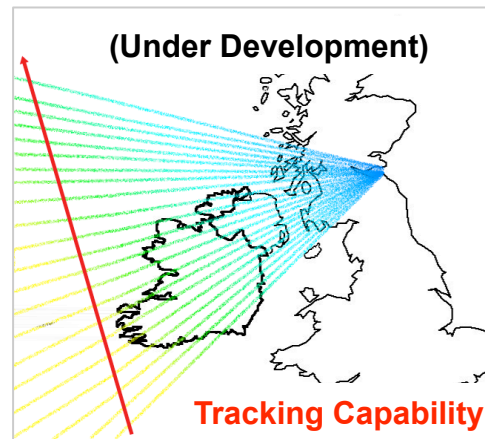
- 3 Engineering Development Unit and 6 Operational Simulators delivered in December 2014
 - Increased fidelity to support verification of increasingly complex flight loads as the instruments begin to show their age. Including Fault injection for training purposes
 - Backwards compatibility to support EOS/NPP missions
- LaRC is ramping up its team support for the JPSS simulators effort
 - Joe Del Corso has been assigned as CERES DPM for simulators
 - Chris Gamboni hired to support engineering development
- The LaRC core team has been successful in vetting most of the simulator requirements with JPSS
 - The JPSS FVTS System Specification (i.e., Volume 6 – CERES Simulator) has been reviewed and the project is working comments and responses with JPSS
- Recent design activities have simplified the implementation for both the EDU and OPS simulators
 - Design for EDU simulators based heavily on LaRC CERES heritage EDU simulator
 - The number of additional boards has been reduced to two interface boards. These board will handle the ethernet interface, anomaly injection, status reporting, and any additional simulations for the EDU.

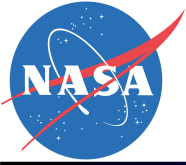


Operational Scanning Capabilities



Clouds and the Earth's Radiant Energy System





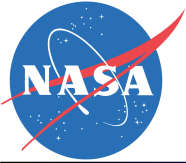
IWG Activities : FM-6 Recovery



Clouds and the Earth's Radiant Energy System

FM-6 instrument recovery activities

- Instrument complete through baseline environmental, functional and performance testing, and calibration.
- Three out-of-family performance issues realized during the instrument calibration campaign.
 - Mirror Attenuator Mosaic (MAM) scatter non-uniformity
 - In-flight Calibration Module (ICM) lamp brightening
 - ICM lamp monitor (photodiode) response decrease
- Northrop Grumman Tiger Teams established
- Instrument currently disassembled and under test at NG



IWG Activities : Future Data Processing



Clouds and the Earth's Radiant Energy System

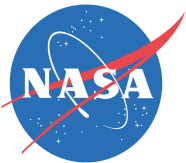
Future Opportunities

Follow-on Procurement : Requirements and SOW development

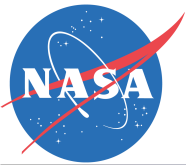
–RFP scheduled to hit the streets in Spring 2013

Future Processing Implementation

- Negotiating path forward for data processing beginning with CERES FM-6 on J1
 - JPSS to initiate incorporation of L1 codes in FY13 for parallel processing of operational products?
 - Code walkthrough at LaRC on 11/2



FM-6 on JPSS-1 Status

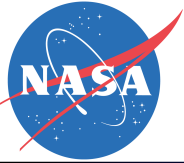


CERES FM6 Status & Near-Term Activities



Clouds and the Earth's Radiant Energy System

- ◆ Project received ~\$5M for FM6 in CY08
- ◆ Allowed for enhanced study phase only, start 11/08
- ◆ Long Lead item procurements authorized 3/09
- ◆ Contract negotiations completed 4/23/09
- ◆ Key Milestone Dates (Preliminary)
 - Authority To Proceed – 5/1/09
 - Systems Readiness Review – 9/22/09
 - Delta Preliminary Design Review – January 2010
 - Delta Critical Design Review – September 28, 2010
 - All major subassemblies delivered to NG, currently in sensor I&T
 - Radiometric Calibration Facility Upgrades Complete – January 2012
 - Pre-Environmental Readiness Review - February 2012
 - Ground Calibration Campaign – Spring 2012
 - *Delivery to storage – Summer/Fall 2013*
 - *Launch Date of Nov. 2016 (TBR)*



CERES JPSS-1 Top Level Status



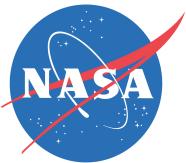
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Status as of last Science Team Meeting

- CERES (FM6) –Instrument complete through baseline environmental, functional and performance testing, and calibration. Three out-of-family performance issues realized during the instrument calibration campaign.
 - NGAS Tiger teams were established to investigate and resolve the out-of-family performance
 - FM6 system acceptance review / pre-ship readiness review postponed until performance issues resolved

Current Instrument Status

- The CERES FM6 Team continues to pursue diagnostics and resolution of the three out-of family performance issues:
 1. Mirror Attenuator Mosaic (MAM) scatter non-uniformity
 2. In-flight Calibration Module (ICM) lamp brightening
 3. ICM lamp monitor (photodiode) response decrease



Radiometric Performance Requirements

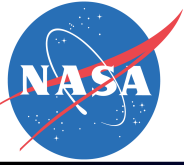


Clouds and the Earth's Radiant Energy System

**CERES is defined as a class 'B' Mission
5-year design Lifetime**

Spectral Region	Solar		Terrestrial		Atmospheric Window
Wavelengths	0.3 – 5.0 microns		5 – 200 microns		8-12 microns
Scene Levels	<100 w/m ² /sr	>100 w/m ² /sr	<100 w/m ² /sr	>100 w/m ² /sr	All Levels
Accuracy Requirements	0.8 w/m ² -sr	1.0 %	0.8 w/m ² -sr	0.5 %	0.3 w/m ² -sr
SOW Stability Requirements		0.14 %/yr		0.07 %/yr	
FM5 Accuracy Capability		1.7 %		0.7 %	
FM5 Stability Capability		0.32 %/yr		0.12 %/yr	
Climate Stability Goals		< 0.6 w/m ² /dec < 0.03 %/yr		< 0.2 w/m ² /dec < 0.02%/yr	

Current efforts are focused on improving traceability within the reflected solar bands (Short-Wave and Total channels) by enhancing the ground calibration in the short-wave region for FM-6.



CERES Ground Calibration



Clouds and the Earth's Radiant Energy System

Radiometric Calibration Facility

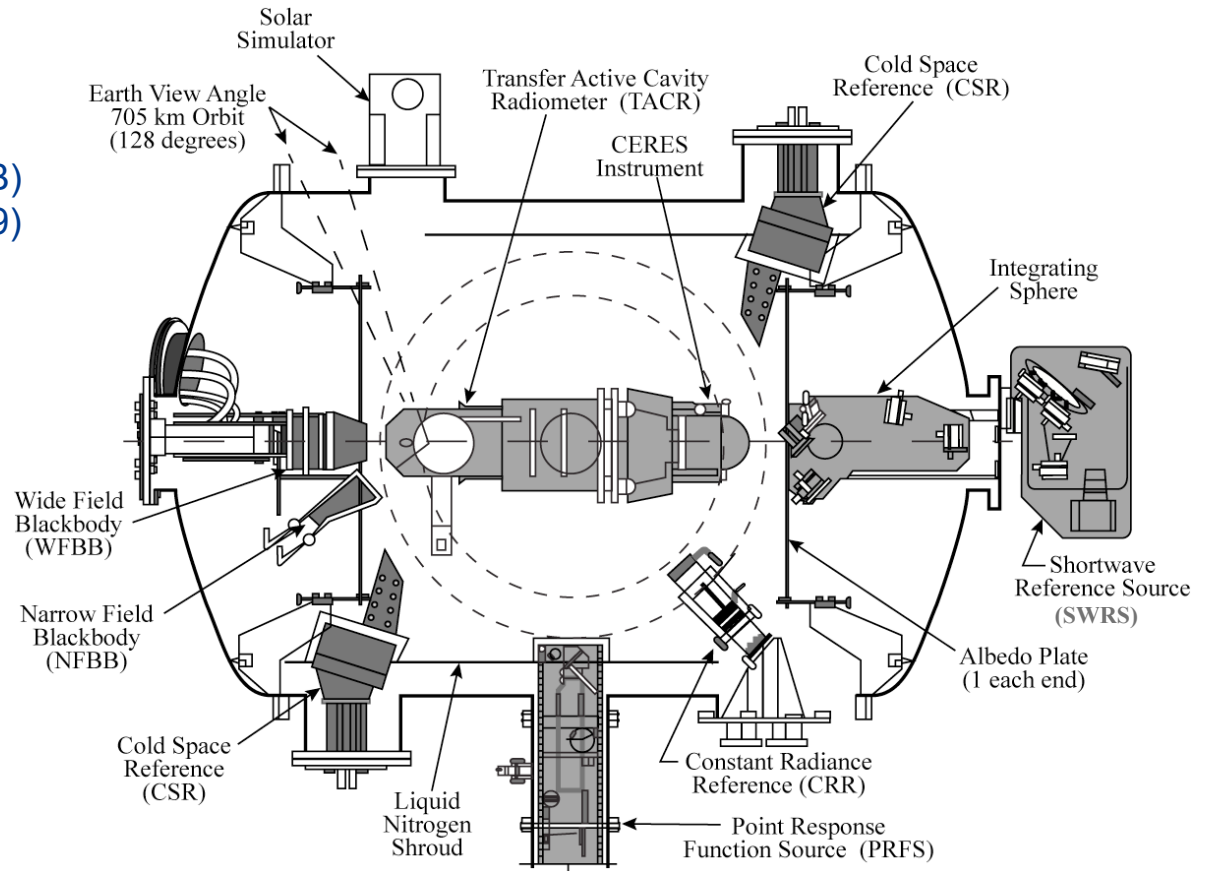
- ◆ Heritage ERBE calibration facility
- ◆ Revamped for CERES in 90's

Thermal IR Bands

- Narrow Field of View Blackbody (NFBB) is primary standard (emissivity >0.9999)
- 12.5 cm Wide Field of View Blackbody (WFBB)
- Cold Space Reference (CSR) blackbodies

Reflected Solar Bands

- SW reference source (SWRS) with minimum LW variations and spectral characterization capability
 - 13 discrete bands between 420 and 1960 nm
 - 5 cm integrating sphere with associated optics
- Cryogenically cooled Transfer Active Cavity Radiometer (TACR)





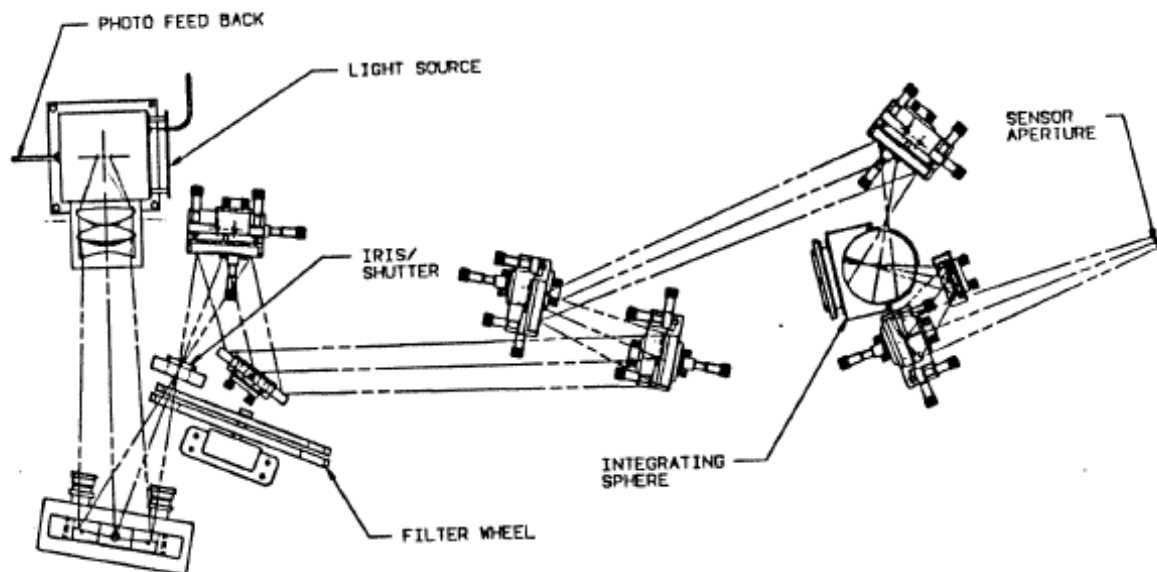
RCF Shortwave Reference Source (SWRS)



Clouds and the Earth's Radiant Energy System

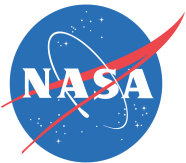
The SWRS consists of a stabilized Halogen lamp fed into the RCF via optical train

- 8 mirrors, 1 triplet lens set, 13 filters in a filter wheel, an iris aperture, a vacuum window and an integrating sphere



- 250-watt QTH lamp source @ ~3100K
- Precision power supply with <0.4% rms radiance ripple
- Photofeedback system using a thermally-stabilized silicon photodiode

PARAMETER	VALUE
Filters used for CERES Calibration (center wavelengths in μm)	0.42, 0.46, 0.51, 0.62, 0.71, 0.81, 0.90, 1.00, 1.15, 1.25, 1.35, 1.63, 1.94
Broadband Radiance Range ($\text{W}/\text{m}^2/\text{sr}$)	13 to 2500
Exit Port Angular Subtense (degrees): cross-scan; in-scan	3.5; 7.8
Radiance Uniformity (peak to valley): aperture; field angle	$\pm 0.5\%$; $\pm 1.5\%$
Radiance Fluctuation (0.01 sec. to hours)	$< \pm 0.1\%$ (1-sigma)
Thermal Stability and Uniformity (Kelvin)	± 0.5
Sphere Operating Temperature (Kelvin)	< 85



FM 6 Ground Calibration Improvements



Clouds and the Earth's Radiant Energy System

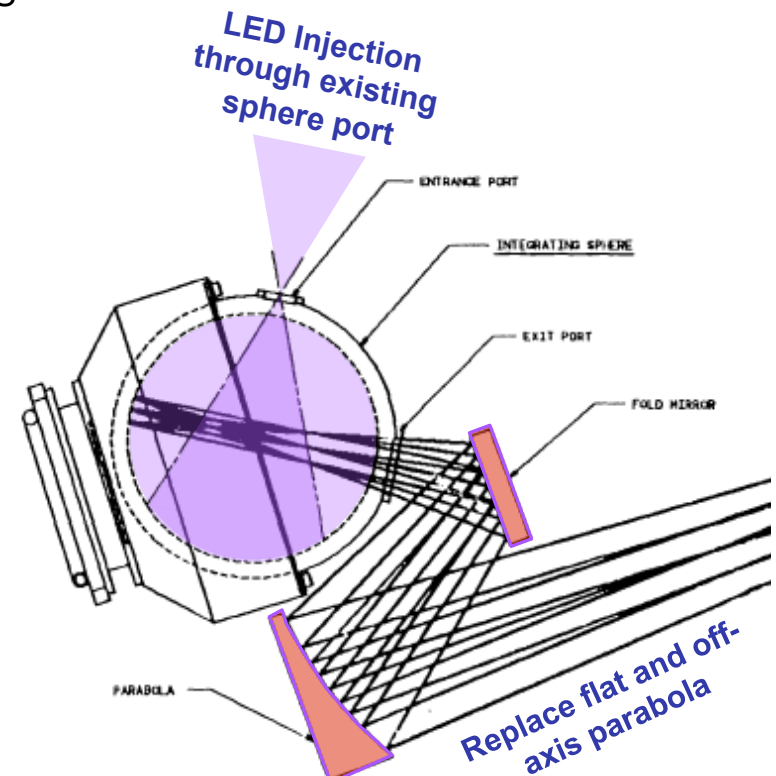
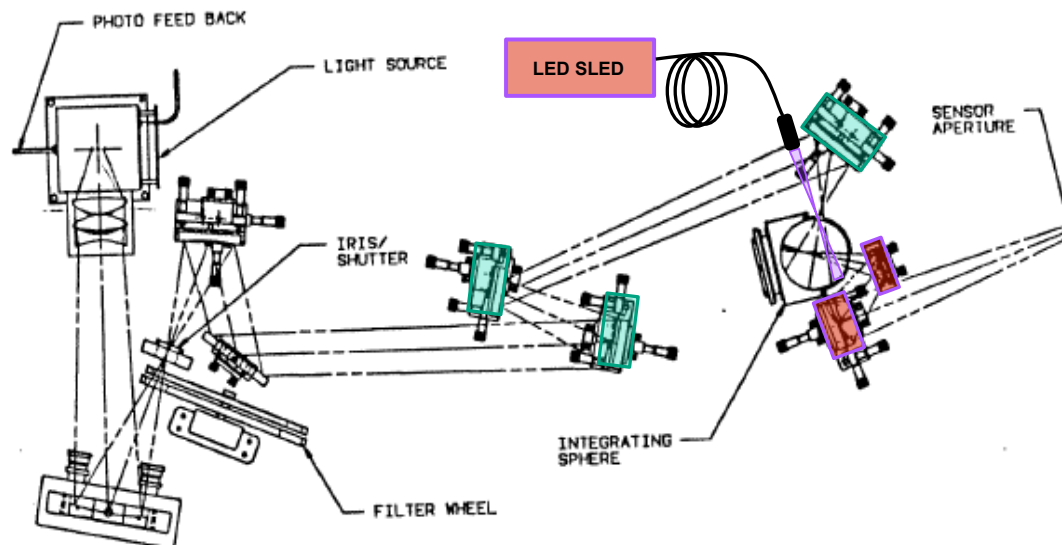
SWRS Improvements

◆ Improve SWRS optics

- NASA has contracted mirror replacement – enhanced aluminum coatings on mirrors following sphere
- Option to replace additional mirrors in SWRS optical train to improve throughput

◆ Supplement SWRS for increased radiance at the shorter wavelengths

- NASA has contracted LED augmentation to existing SWRS
- Discrete LED sources at 365nm, 385nm and 405nm
- Option for additional LED coverage up to 970nm
- Option for future coupling of coherent sources

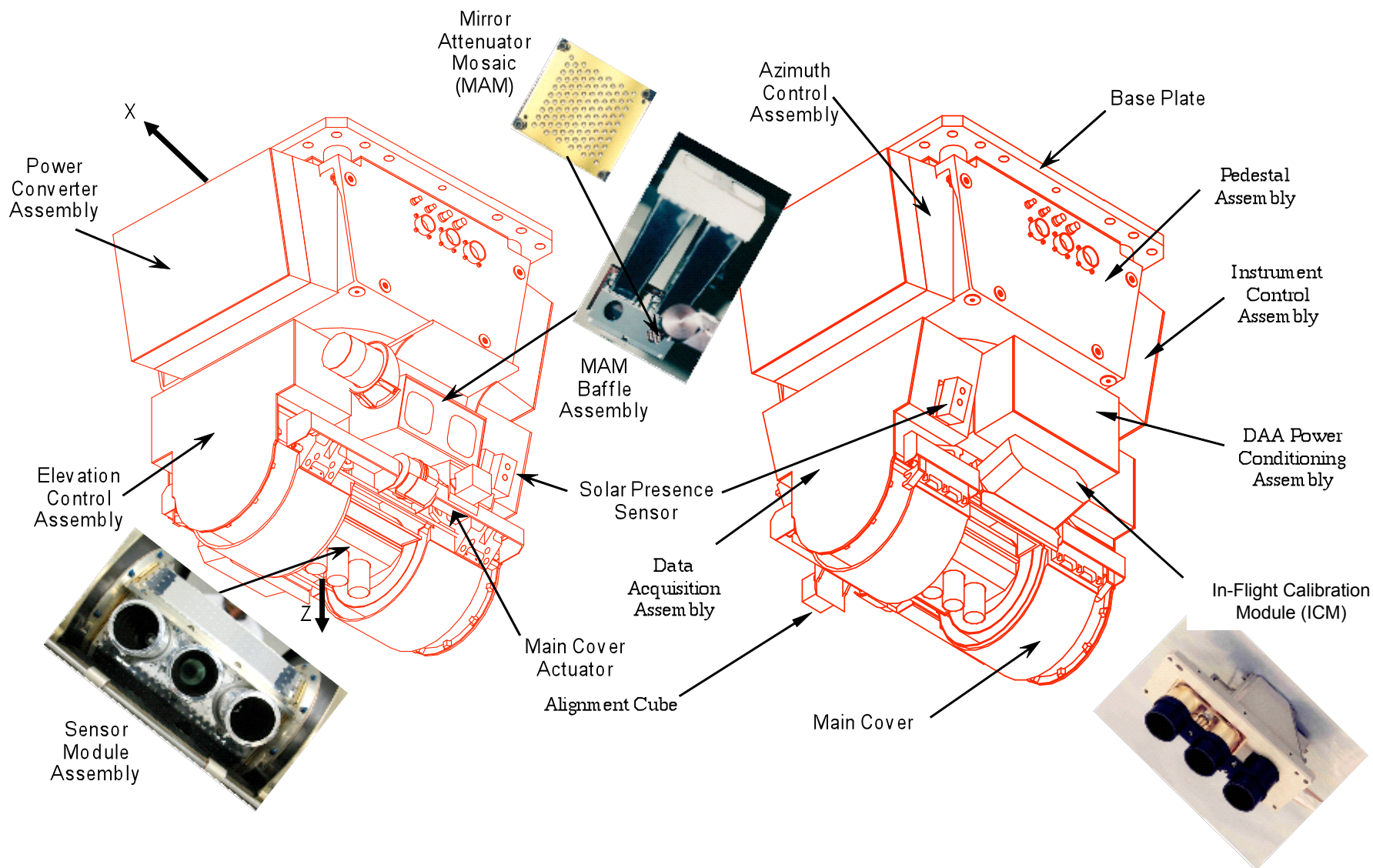


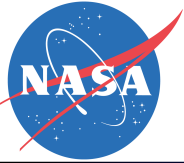


CERES Sensor Description



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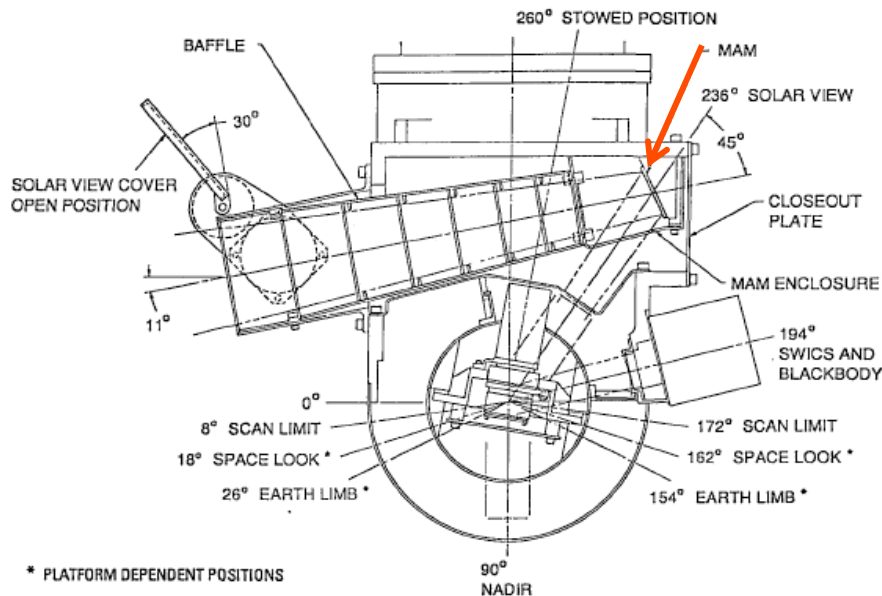


CERES FM6 MAM Overview



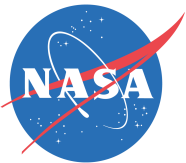
Clouds and the Earth's Radiant Energy System

- Mirror Attenuator Mosaics (MAMs) diffuse and attenuate incident solar energy so that the CERES Shortwave and Total Channels are presented with repeatable, on-scale radiance scenes over the range of incident angles experienced during periodic, on-orbit, solar calibrations.
- MAMs for FM6 are different than prior flight units
 - Substrate = Diamond Turned Aluminum (FM6) vs. Electroformed Nickel
 - Coatings updated for improved resistance to Atomic Oxygen



CERES Mirror Attenuator Mosaic

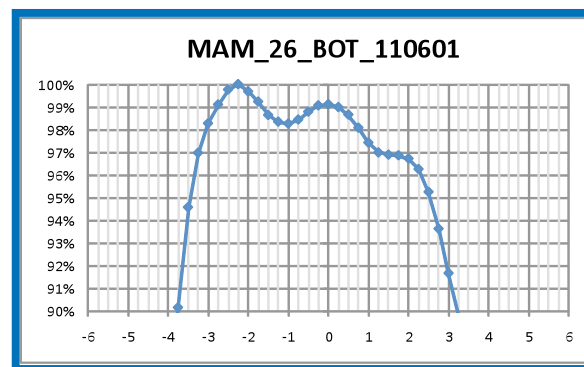
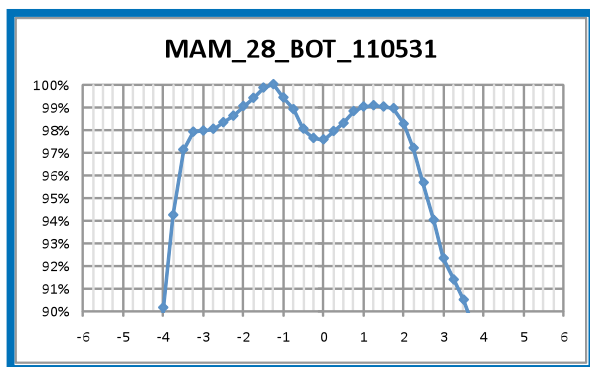




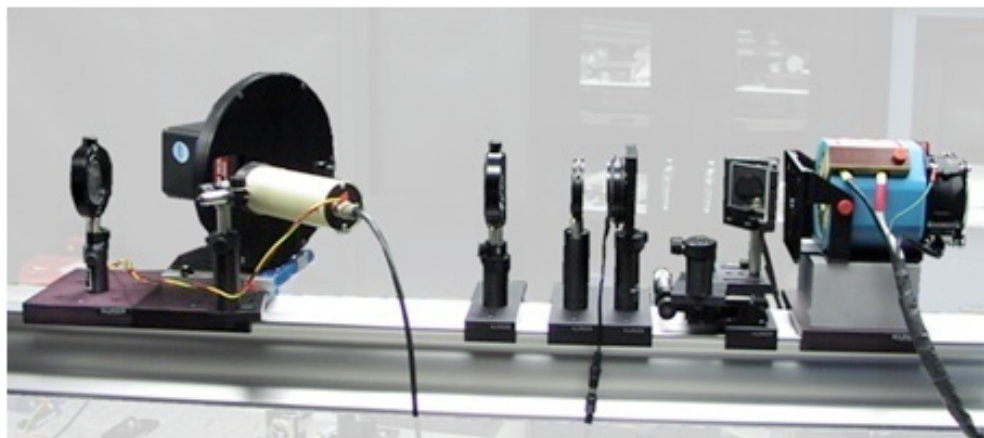
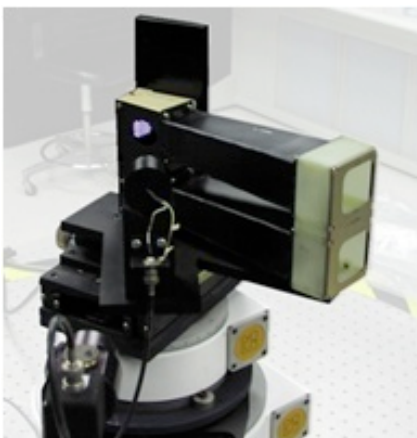
JPSS-1 CERES MAM Component-Level Scatter Uniformity Results (2011)



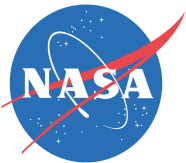
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For scatter testing, the assembly is rotated in a single axis through a collimated, white light source (xenon arc lamp)



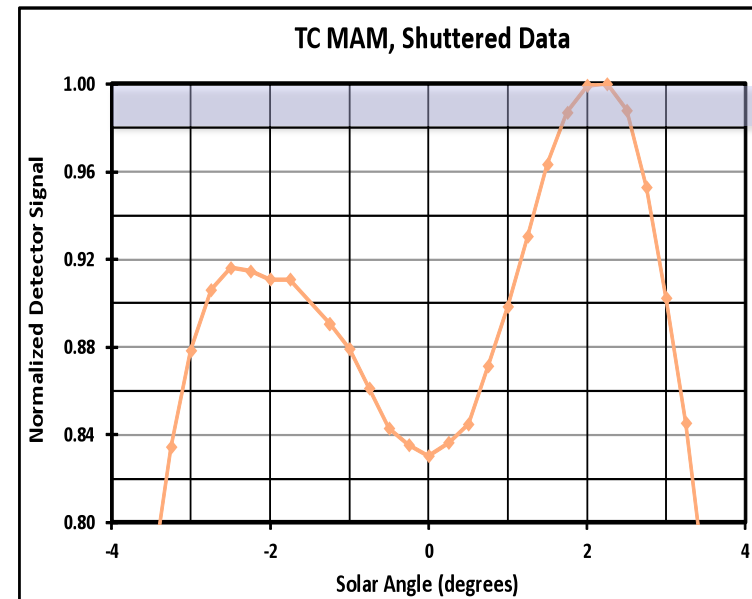
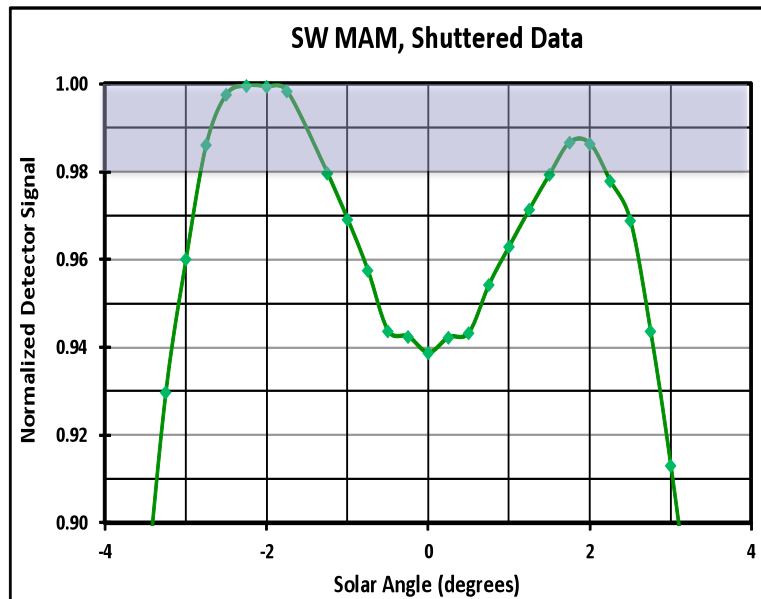
MAM performance GOAL: uniformity to $\pm 1\%$ over 4.5 deg. solar angle



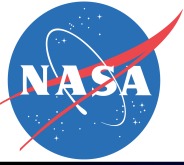
JPSS-1 CERES FM6 MAM Scatter Data Collected During Calibration (May 2012)



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- Scatter uniformity is ± 3 to 8% , significantly different than component-level test data, and not close to the $\pm 1\%$ performance goal.



FM6 Performance Investigation (Status)

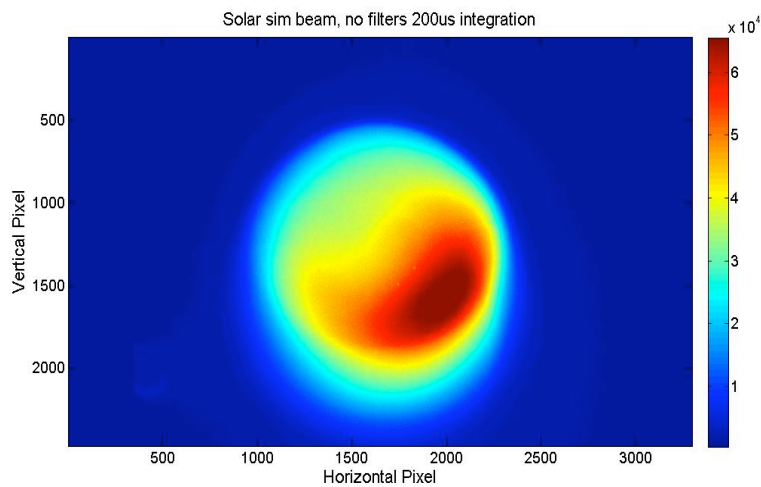


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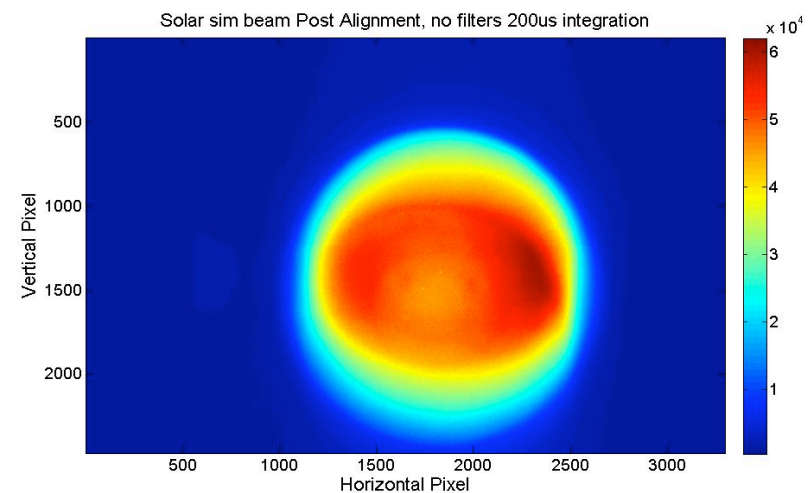
Investigation results for the MAM

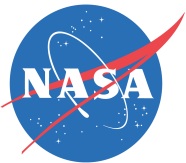
- Initial investigation results revealed that the output beam from the solar simulator used during scatter uniformity testing in the Radiometric Calibration Facility (RCF) was non-uniform (out of focus and somewhat misaligned).
 - This appeared to be the probable root cause for the level of MAM scatter non-uniformity displayed during calibration testing.

Solar Simulator Beam Out-of-Focus



Solar Simulator Beam In-Focus





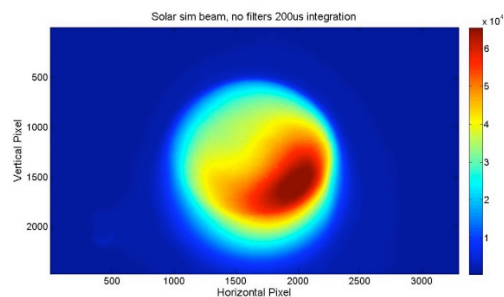
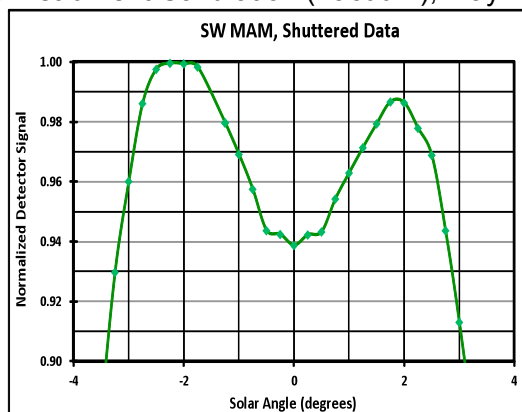
FM6 MAM Investigation (cont.)



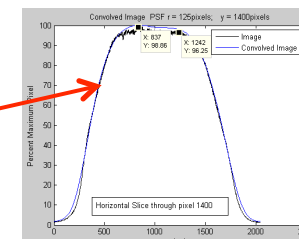
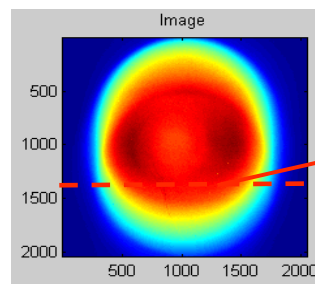
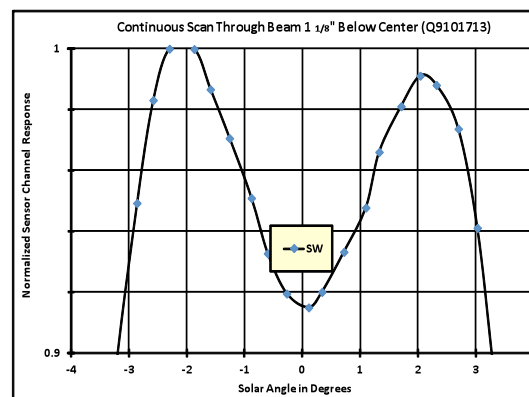
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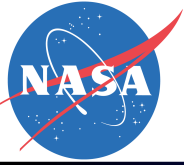
- A second MAM scatter uniformity test with a focused and characterized RCF solar simulator beam has been conducted; however the data from this second test has not exonerated the MAM flight hardware and more testing is needed.
- Solar Simulator output beam uniformity was optimized prior to start of test. Still ~13% non-uniformity, but most likely the most uniform its ever been

FM6 Instrument Calibration (Vacuum), May 2012



MAM Scatter Re-Test (Ambient), September, 2012





MAM Scatter Uniformity Investigation: Next Steps



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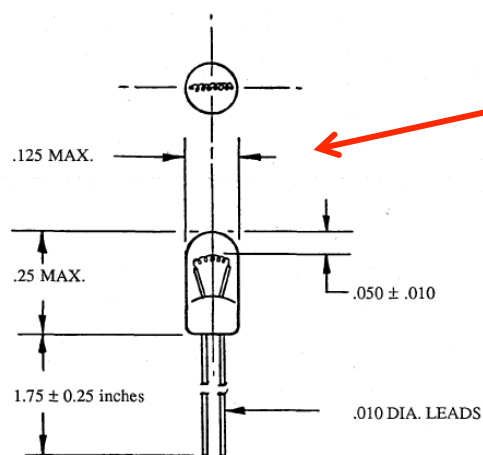
- ◆ **NGAS planning toward another instrument-level MAM scatter uniformity test using the RCF solar simulator**
 - FM6 will be attached to a mounting plate, interfaced to an existing L bracket and rotary table such that the center of rotation is at the MAM location
 - Placing the center of rotation at the MAM location prevents relative translation (eliminates beam non-uniformity issues) and better-simulates the operational geometry
- ◆ **Two diamond-turned aluminum MAMs are being sent to LaRC for component-level study (1 coated, 1 non-coated)**
- ◆ **NGAS is also working toward establishing mandrels to reproduce electroformed nickel substrates per the heritage MAM design if the diamond turned aluminum MAMs are determined unsuitable for flight**



CERES In-Flight Calibration Module

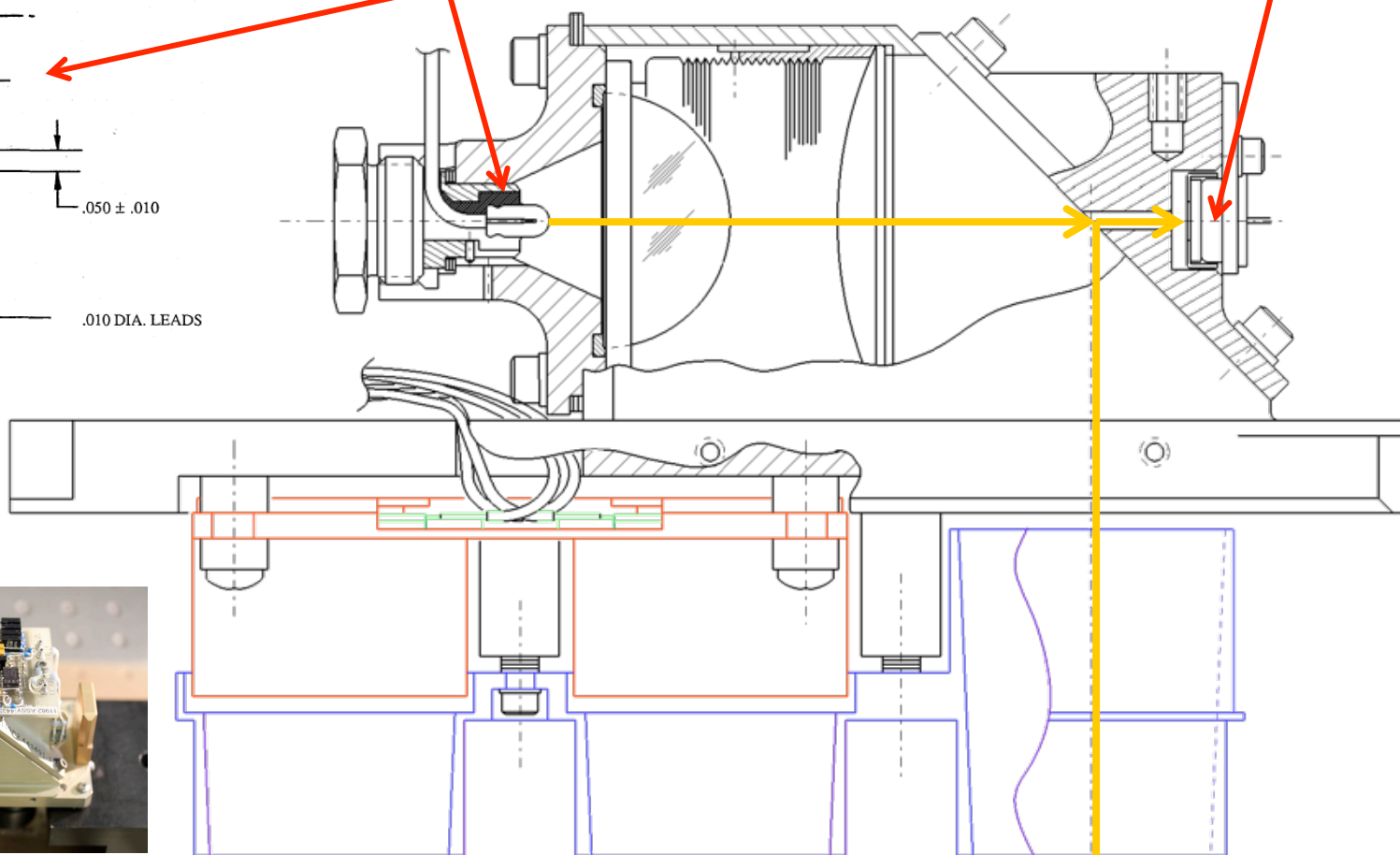


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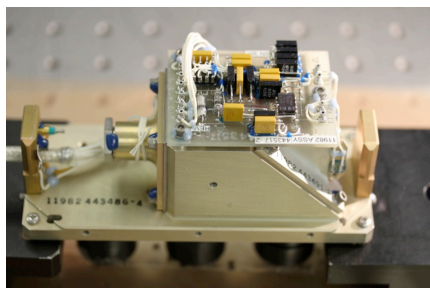


Tungsten Filament Lamp

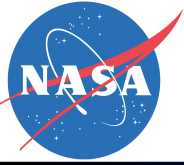
Reference Photodiode



Light out to Short Wave Sensor



FM6 ICM with cover removed



Instability of SWICS Lamp and Photodiode

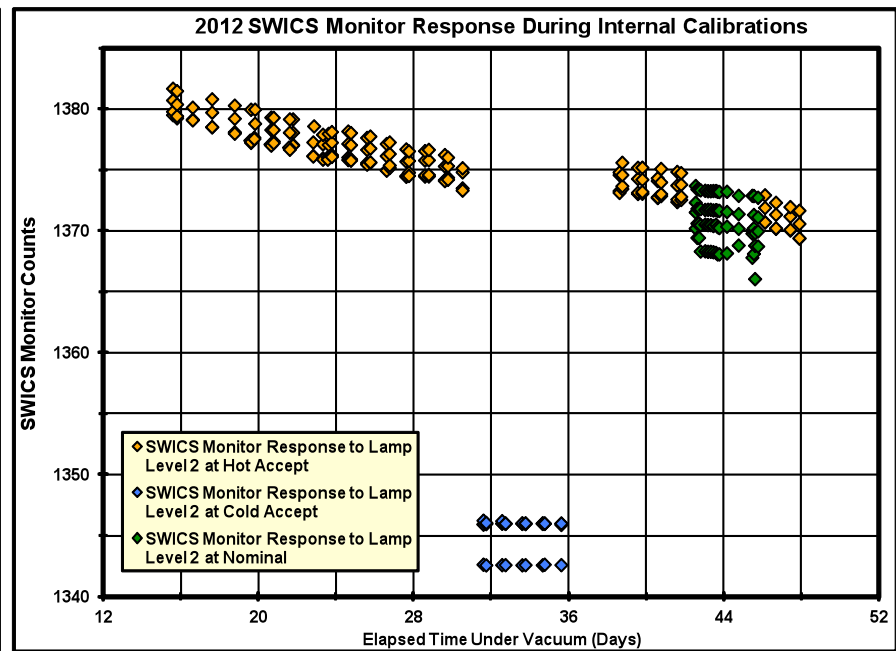
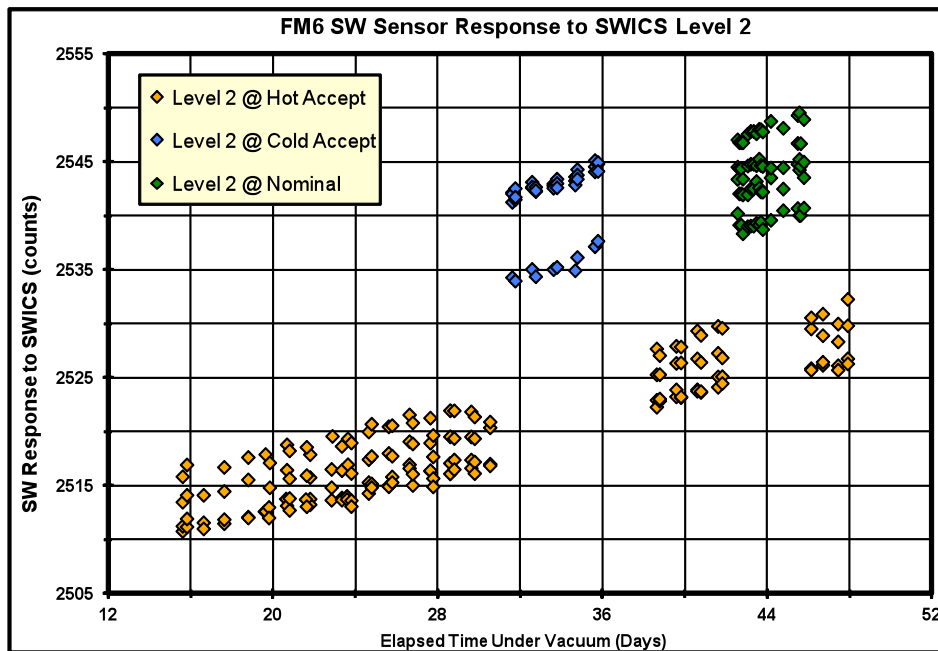


Clouds and the Earth's Radiant Energy System

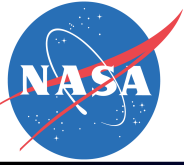
*The trends in the data below should be **flat**.*

SWICS Lamp appears to be getting brighter

Photodiode response appears to be decreasing, not following SWICS Lamp



- ◆ Shifts with temperature are artifact of sensor and BB heater drive ground bias effect
- ◆ PD Data uncorrected for apparent source drift
- ◆ PD Response Drift Rate is a function of Instrument Temperature

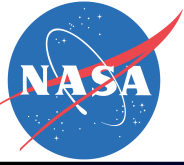


ICM Lamp and Photodiode Investigation: Recent Effort and Current Status:



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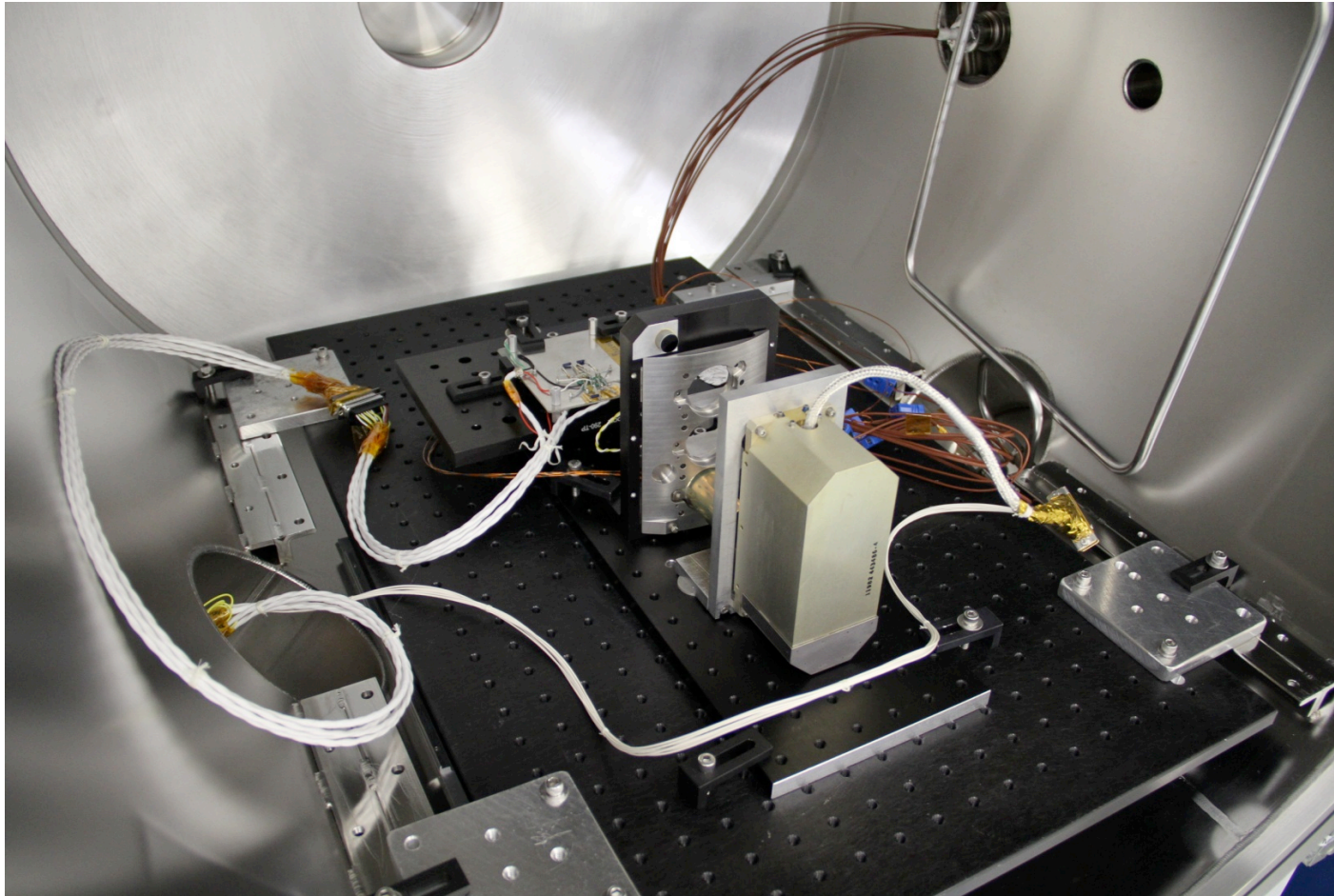
- ◆ **Over the last two months, NGAS has developed and validated a vacuum test facility to be able to conduct performance test of the ICM module as a stand-alone unit.**
- ◆ **The ICM was removed from the FM6 instrument in late September and stand-alone testing under vacuum was initiated on October 8.**
 - Testing under vacuum for lamp and photodiode performance stability is planned to span 3 weeks.
 - This diagnostic test will evaluate whether some of the same performance trends observed during instrument-level testing are observable at module-level testing to confirm that the focus is to remain on the ICM module.
 - Initial results are:
 - Lamp monitor photodiode (PD) is drifting in response in the same direction as it did during operation under vacuum at the instrument level
 - Lamp is drifting in the same direction as it did under vacuum at the instrument level.



FM6 ICM Installed in Vacuum Chamber



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- Contamination witness wafers from last vacuum checkout came back nominal
- A fresh set of wafers was installed with the ICM prior to closing chamber door